

The *Heaven and Earth* Virtual Reality: Designing Applications for Novice Users

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There are more things in Heaven and Earth, Horatio, than are dreamt of in your philosophy. Hamlet Act I, Scene V, William Shakespeare.

Abstract

When people first experience Virtual Reality they are bound to come away with some misconceptions as to the potential and usefulness of the technology due to the hype which has recently surrounded it. Thus, there is a need for a *novice environment* in which first-time (novice) users can get acquainted with the basic technology and its potential by means of a demonstrative application. The goals of such an environment are to give a 'taste' of the technology and a hint of how valuable it will be when it matures. This paper describes a novice environment called the Novice Design Environment, in which users can perform basic interior decoration design. A design metaphor called the *Heaven and Earth* is used in order to customize the design. This environment has been tested with a large of novice users. An evaluation of tools for supporting novice interaction and "rules of thumb" for building virtual realities for novices are presented.

1.0 Introduction: Why VR for novices?

Virtual Reality is a relatively new and still maturing technology. Hence many of its users are novice who typically will have heard lots of hype but are only able to personally experience only a short low-fidelity demonstration. In many cases, they come away with a negative impression. Novice users are, in general, overwhelmed when they first come into contact with VR due to the amount of unfamiliar imagery and actions that they are required to assimilate and perform. Thus, there is a need for a *novice environment* in which novice users can get acquainted with the basic technology and its potential by means of a demonstrative application. The goals of a novice environment are to give a 'taste' of what VR is all about and a hint of how valuable the technology will be when it matures.

As a whole, this novice environment should provide users with a positive VR experience, one that is easy to learn and to perform in. They should feel in charge of the situation, instead of being taken 'blindly' through a canned demonstration.

A primary concern in developing such a 'novice environment' is the kind of task the user will perform; a training task, a design task, or perhaps a game? We chose to develop a 'room layout and interior decorating-type' design task, in which the user is given an empty or partly furnished space whose components (chairs, tables, doors, rooms) can be rearranged, duplicated, their color changed, etc.

The decision was made on the basis that this is the type of design that can be accomplished with ease in a VR environment given its interactivity and its three dimensional nature, as compared to using conventional 2D input devices and stationary monitors as output devices. Designing by means of conventional technology requires a long learning period. If the 'novice environment' manages to illustrate that the design process can be made simple using VR technology, then the impact on the user will be even greater. At the same time, this design task, besides being a familiar task and encouraging creativity, is very flexible in that its goal, unlike games or training, is judged in terms of aesthetics (which are subjective) and not in terms of failure to reach a score or complete a job, thus ensuring a 'positive' experience for the user.

The general task requirements of a novice environment are:

- A simple enough interface for the user to be able to grasp almost immediately
- A way for users to pick up and position objects
- A way to move the user's vantage position in small and large jumps
- A way for users to search for objects needed for composition
- A way for users to compose objects

At the Institute of Systems Science, part of the National University of Singapore, a novice design environment called *The Heaven and Earth Novice Design Metaphor* was built and demonstrated to hundreds of people at the Singapore Informatics '92 international computer technology exhibition. In this paper we describe the Heaven and Earth system and the experiences gained from demonstrating it to large numbers of novice users.

2.0 A Novice Approach

Design applications are by nature quite complicated. Software packages have dozens of menus and commands to remember, making the learning process difficult and long. Thus, simple controls in the system are not easily combined with the power to do significant work in the virtual environment. Interaction techniques are needed that are simple but highly useable, something like the mouse in the Macintosh which can do many things with just a simple click and drag of the mouse.

The Novice Design Environment is based on readily learnable interaction techniques. It provides a simple way for the user to travel in the system as well as natural ways to grab and move objects around. Additionally, the environment provides a library which is based on the interaction techniques to help users to do object composition and thus to quickly design their own virtual worlds.

The 'novice environment' design relies on a basic VR setup consisting of a tracked head-mounted display and a simple 3D input device, such as the Ascension Bird or Logitech's 6D mouse. This configuration, as shown in Figure 1, provides the minimum necessary to break the barrier from the 'conventional' 2D environment and is simple enough for the novice user to assimilate on a first encounter.

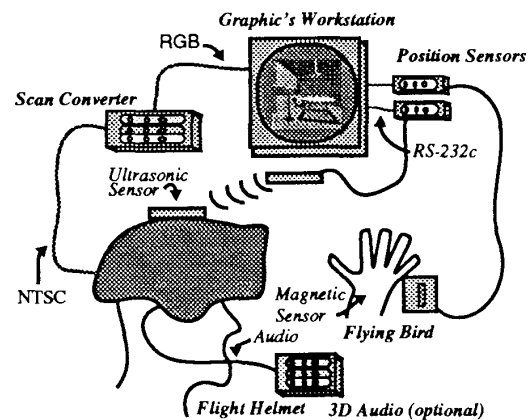


Figure 1 Novice Demonstration Configuration

2.1 Travel

The *right way* to navigate in Virtual Spaces is still one of the great unanswered questions in Virtual Reality technology. In earlier work, such as SemNet at MCC [FAIR88], and the Information Visualizer at Xerox PARC [ROBE91], several approaches have been demonstrated. The only conclusion is that each method works well in some cases, but not very well in general. In the initial Heaven and Earth prototype, we implemented three different navigation techniques in order to find the one most effective for novices.

The first technique, *Flying Hand*, was based on the user making a particular hand gesture (i.e. pressing a button on the 'bird'). The orientation and location of the hand in relationship to the user's head determined the direction and the velocity of movement. To move in the yaw direction, the user rolled the hand in the direction desired.

The second technique, the *Floating Guide*, followed from the observation that most head-mounted-display clad users have a very difficult time finding buttons on hand positioning devices. In this technique, a small sphere floats with the user whose head moves in the virtual space. To change position, the user moves the control hand to this sphere, which always lives in the upper right corner of the field of view. The technique then works like the Flying Hand technique until the sphere is released.

In evaluating the above two techniques with test subjects, it was found that both were just too difficult for many of the novices to pick up quickly and so the authors **cheated**; the operator was given a mouse-based interface, and if users could not figure out how to move, the operator would do it for them!

Finally, during a discussion with Captain Pang Chiun Min of the Singapore Navy, he mentioned that in the situation room aboard ships, the ship captain is surrounded by officers manning consoles and that the captain need only to *lean over* to talk to them and examine their displays. This leaning solution was found to be amazingly successful with both novice and advanced users. Its greatest advantage is that it relies on the user's head position, and not on the user's hand position as typically done. This frees the hand for object manipulation and allows the user to both move and manipulate objects at the same time¹.

There are two versions of *Lean-Based* navigation, one used for movement around a central point and the other for movement from place to place. In the first version, *absolute leaning*, the user's actual head displacement p is modified by an exponential function to distort the movement v in

$$v = \frac{1}{k} \cdot (e^{k \cdot p} - 1)$$

the virtual world. Small physical movements are mapped into equal movement in the virtual space. But as the user leans further at the waist, the movement is magnified in virtual space. Using this technique, users can easily reach an object 30 *virtual feet* away by physically turning and leaning towards it with hands outstretched. By simply straightening up, the user may fetch the object to the original location.

The second lean method, *relative leaning*, is similar to athletes breaking the tape at the finish of track events, by leaning into it. This method is extremely useful for movement across long distances. The users just lean in the direction they wish to travel; the amount of lean determines the speed of movement. If they overshoot, they need only to lean backwards. The difference

1. [BOOL88] also found that when subjects were asked to navigate on a virtual racetrack, subjects would lean into the turns expecting this to cause them to turn.

between the methods, is that in absolute leaning the position changes around a central point, whereas in relative leaning the movement continues in the direction of the movement.

A final navigation problem is how to allow users to move their view point in the 'yaw' axis (how to turn around). Given a swivel chair the user can 'physically' do it, but since they are attached with lots of wires it is best to have a 'virtual' solution. Users normally look left/right ('yaw') and up/down ('pitch'), but rarely roll their heads: since the 6 degree of freedom sensor does allow that movement, the roll motion, similar to the relative leaning, maps the head-roll into the body yaw position.

2.2 The Grab and Throw Interaction Technique

One of the many interesting things about the Artificial Reality Kit (ARK) by Xerox PARC [SMIT87] was the use of a small hand instead of the typical mouse cursor. Users quickly discovered that the hand, even though controlled by the traditional mouse, could be made to close and that it could also be used to toss objects.

Exploiting this result, any button on the hand positioning device causes the virtual hand to make a fist (all buttons were used because it was found that novices could not find the 'Right' button when using a head-mounted-display). Once a fist is made, the hand becomes 'magnetic', so that any object that is 'reasonably' close is captured by the hand. By moving the hand and releasing the button, the velocity of the hand at the time of the release is given to the object and it moves at that rate.

Most novices had little problem with performing this behaviour, but a significant subset found it difficult to remember to release the button only at the 'end' of the throw. That is some would let go of the button and then throw the object or would not release at all. During conversations with Dr. Bill Curtis (CMU and MCC), he suggested that 'flick'-based throwing would make it easier.

In *flick* throwing, a history trail of hand movement velocities are kept when the hand is moving. When a 'sudden' reduction in the velocity is noted, the object is released. This eliminated the button release requirement and it was found that anyone can quickly produce this behaviour with reasonable control.¹

The resultant grab-and-throw interaction technique can be compared to the click-and-drag Macintosh technique. This easily learned and performed behaviour is a general interface technique applicable to controlling many kinds of system behaviour.

2.3 The Heaven & Earth Design Metaphor

The techniques described above for grabbing, throwing and moving objects within the virtual space provide the basic capabilities necessary to interact effectively in the novice VR environment. However, in order to construct custom spaces it is necessary to obtain new objects to add to the existing set: the *Heaven and Earth* design metaphor provides a mechanism to achieve that.

Above the current virtual space, or 'Earth', is a library called 'Heaven'. Heaven contains all the basic building blocks for assembling rooms, hallways, and furniture objects.

1. Aristotelean physics are used for the movements of the object. Aristotle's physics provides a coherent set of physical laws which predict physical events less well than Newton's, but fit human expectations better. Being simpler and cheaper to implement, they also give smoother VR simulation behaviour than the usual classical mechanics [POST 93].

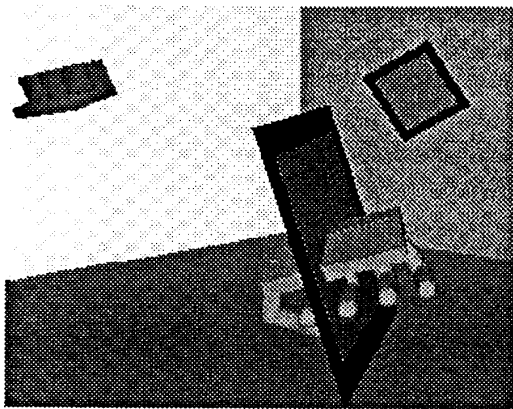


Figure 2 Copying Objects in Heaven

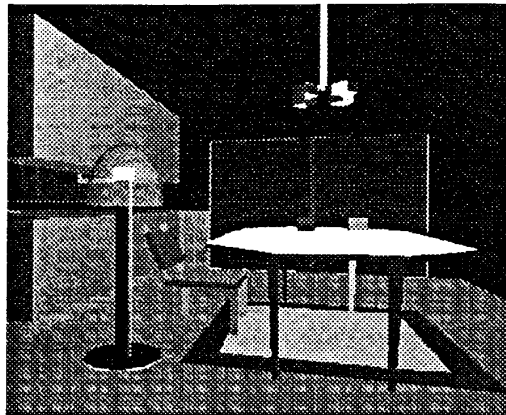


Figure 3 Typical Novice Designed Room

When a user wants to add a new object such as a doorway, a carpet, or a table, the user makes a fist and points up towards the ceiling. The user then rises up through the ceiling and appears within a circle of slowing rotating objects.

The users can then easily make a fist and lean towards a desired object. When reasonably close the object is 'grabbed'. Unlike the behaviour in Earth, the grabbing operation copies the object grabbed. A grabbed carpet is shown in Figure 2. The user can then point towards the floor and float back to Earth for 'throw' placement of the object (see Figure 3).

Initially, the 'gesture' for moving to Heaven and back to Earth again was the same, an upside down fist. To the authors' astonishment, it was found that some users could not comfortably turn a fist over. Also, many had to be reminded that once that the gesture was completed, they could return their hand to normal. The pointing up and down gestures were immediately obvious to users and reduced the ambiguity of the task.

2.4 Teaching a Sense of Self in Virtual Reality

Many users, intimidated by the new technology and with proactive inhibition from their previous computer experience have difficulty making the cognitive leap that they are indeed in the virtual space. The hand and head sensors seem very much like magic and something relatively obvious such as this "disembodied hand in the screen is really your hand" might be hard to understand.

A special 'mirror' creature called Waldo was created both for instructing single users and demonstrating for a larger audience. Waldo, shown in Figure 4, acts much like a mirrored version of the user. When the users moves their heads, sit down, waves, or 'walk', Waldo mimics the movement. It gives a chance to see oneself in virtual reality.

3.0 Evaluation of the Heaven-and-Earth Design Metaphor

The novice design environment system was exhibited at the Singapore Informatics 92 where it was experienced by hundreds of naive users directly, and thousands of users as spectators.

The observed problems were collected and solutions were implemented and further tested. In this section several 'rules of thumb' in the design of VR environments for novices are described

3.1 Buttons

The developers of Macintosh got it right, a single button is best for novices. Once the unaccustomed head-mounted-display is put on, almost no users can by touch tell the difference

between a left, middle, and right buttons. If the positioning device has multiple buttons, they should all be set to the same function.

Unfortunately, previous experience with the ubiquitous computer mouse causes proactive inhibition. Many users have a tendency to 'click' at objects. In the Grab and Throw interaction, users must close the fist with a button down press, move the objects and release the object with a button up release. Typically, a reminder about "how do you pick up a glass of water?" is enough to instruct users in how to do Grab and Throw.

3.2 Navigation

Giving the user the ability to move in even the most simple virtual space is challenging, particularly given the immaturity of the technology. Disorientation is thus a significant problem. 'Mode-based' navigation- where the user, while navigating, can do nothing else is quite frustrating for users. Typically, a user will be reaching for an object and find it just out of reach. This requires the switching into the navigation mode for a moment and then returning to grab mode.

Lean-based navigation seems stunningly effective as a navigation paradigm for reasonably complex physical spaces. Users typically overshoot the first time they try it, but after saying "wow" and rocking back and forth they grasp the concept extremely fast.

'Rolling' the head to move the user in the 'yaw' direction is very effective for most users, but many find that heavy head-mounted-display makes the movement awkward.

3.3 Grabbing Objects

Reaching out and grabbing objects in the environment is a very well learned behaviour in the real world, and is the kind of 'natural' behaviour that virtual reality is trying to exploit. Unfortunately, the current VR device technology makes even this 'obvious' behaviour difficult.

For instance, with a limited / fuzzy field of view and because of system lag, a user often seems to be afraid of losing the hand and so constantly keeps it in front of the face. As a result, it often fills much of the display and occludes details of the virtual space. Even worse, if the user picks up some large object such as a 'sofa' it might be possible to see nothing but sofa! Placing the hand over the object itself is difficult because the system doesn't give enough feedback about the distance of the objects from the hand.

Many of these problems can be addressed by modifying the physical laws of the virtual spaces and of the users' virtual bodies:

Giraffe Necks - If the body of the user is modified to have a neck like a giraffe, then 'leaning' will allow the user to move very rapidly over an entire room. This is particularly useful when the desired object to be picked up is 'just' out of the reach of the user.

Mr. Fantastic Arms - Making the user's arm stretchable and extra long (i.e. 7 feet) both gives the user an extra reach and keeps its graphical appearance smaller so as to not occlude the other objects.

Magnetic Hands - Giving the hand 'magnetism' where the user needs only be 'close' to objects in order to pick them up and 'hooverism' where the user need only be above an object makes the selection of objects easy. When a large object is grabbed, it is 'shrunk' to keep it small enough to manipulate and allow the user to see where to place it.

3.4 Gestures

Given only two input devices, the head-mount-display sensor and the hand sensor, the amount of user interaction is quite limited. It is tempting to use particular sensor orientations (i.e. hand

sensor upside down) and gestures defined in time (i.e. draw a circle with the hand sensor) but the evaluation shows that even the most straightforward gestures are hard for some of the novice user population.

In particular, the initial gestures of rolling the hand sensor clockwise and counter-clockwise for changing one's orientation in the yaw access, and turning the hand sensor upside-down for moving between Heaven and Earth, were quite difficult for a surprising number of users.

For novices, it appears that it is more appropriate to use position rather than orientation for defining gestures. For instance, not only was raising the fist towards heaven more natural, but users would immediately realize that upon arriving in Heaven that they could lower their hands.

4.0 Software Platform

The Novice Design Environment is implemented using the **Bricks** object system [SERR92], a toolkit that provides a set of objects useful for rapidly defining virtual reality applications.

Bricks runs on Silicon Graphics and IBM RS6000 workstations. **Bricks** gains much of its capabilities from its Starship, its implementation language [LOO91], a frame-based, object-oriented language, which is interpreted but runs extremely efficiently.

5.0 Conclusions

Novice environments must be designed with more attention to what seems immediately natural than to the power that might ultimately be possible in a user-surfy system. 'Heaven and Earth' illustrates the possibilities for an immediately accessible VR environment.

In this paper, several new interaction styles focused on novice users were described. Several conclusions in the form of 'rules of thumb' describe how to handle buttons, navigation, grabbing of objects, the user body, and gestures. The Novice design environment continues to be improved while the concepts gleaned from the experience of demonstrating it to hundreds of novice users are being turned to the development of the 'Artisan Design Environment'. Using this environment, motivated users will use more powerful tools to immersively construct more complex virtual realities focused on specific design tasks.

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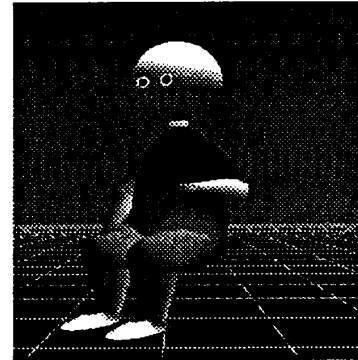


Figure 4 Waldo / Mirror Image of Novice